A Velocital Preconditioner for Reducing Artifacts Introduced by DCT-Based Compression

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Abstract

The Discrete Cosine Transform (DCT) along with frame differencing, normalization and quantization are used in a variety of video compression techniques that are designed for image sequences. These techniques produce lower quality image sequences suffering from artifacts such as blocking, frame repeats, blurring, image persistence and edge business. The artifacts tend to increase with higher spatial-temporal information content in the image sequence. Bad image frames such as those suffering from erratic noise can produce higher spatial-temporal information content and contribute to additional artifacts after being sent through a transmission/compression system. A preconditioner can be applied before the video is encoded in order to produce a higher quality input image sequence and less artifacts at the output. An appropriate objective metric that can detect noisy image frames can be added in the preconditioner to ensure high quality input. One such objective metric, called a velocital information metric, has been recently introduced. It has been shown to filter out noisy image frames from infrared image sequences. The results of using the velocital metric as a preconditioner is shown for a digital infrared sequence suffering from erratic noise.

1 Introduction

Standard digital compression techniques such as H.261 and MPEG have been developed for compressing image sequences by encoding algorithms dependent on the Discrete Cosine Transform (DCT), frame differencing, normalization, and quantization. These compression techniques are considered "lossy" since the decoded image sequences are not completely restored but suffer from artifacts such as blocking/tiling, blurring, image persistence, edge business, and frame repeats. The artifacts tend to increase for higher amounts of spatial and temporal information content [1].

Preconditioners can reduce the spatial and temporal information content and thus reduce the artifacts. A preconditioner is used on the input image sequence prior to encoding. We introduce a preconditioner here that prevents noisy images from being encoded and transmitted. Since noisy images tend to increase the spatial and temporal information content, a noisy image filter will tend to reduce the artifacts as well as reduce the total bits transmitted and produce higher quality output.

Our preconditioner is based on a metric we recently introduced [2, 3, 4, 5] to measure velocital information content and to rank the quality of the input images. The metric has been shown to be sensitive to the sudden changes caused by erratic noise. In this paper, we will demonstrate the velocital preconditioner using a 3 second infrared image sequence along with the H.261 compression technique.

2 The Velocital Preconditioner Approach

The velocital preconditioner is envisioned as a computational technique that can be incorporated between the sensor and compression/transmission system. As the sensor collects image frames, a velocital information measure is calculated and assigned to each frame. As we previously reported [4], the velocital information measure is a comparative quality measure. Therefore, lower quality frames are outside the expected velocital norm. The velocital information measure for a 3 second infrared image sequence is shown in Figure 1. A comparison of lower quality image frames and higher quality frames selected by the metric is shown in Figure 2.

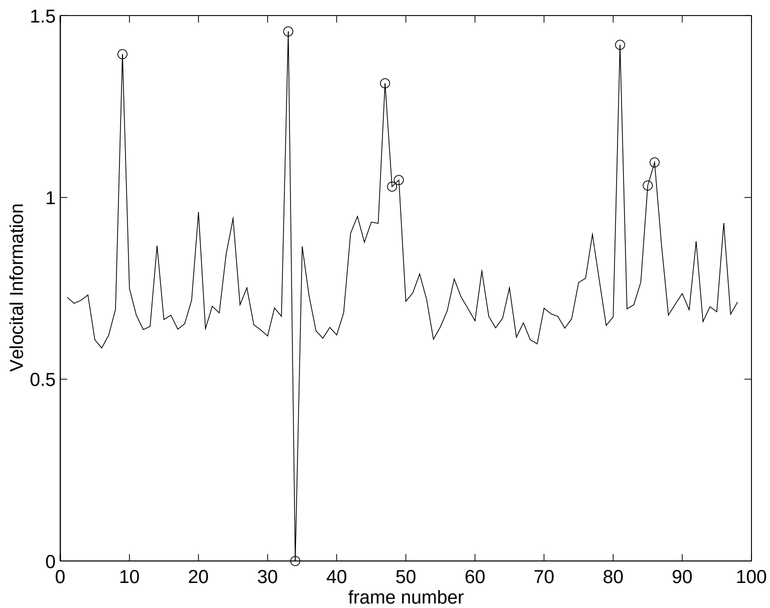

Figure 1: The velocital information content of a 3 second infrared image sequence. The poorest quality frames are circled. Frame 34 has a value of zero because it is a frame repeat.

[width=6in]i44img.eps

Figure 2: As selected by the velocital information feature, the right frames are poorer quality. The left good frames are the frames one frame prior to the frame selected as poorer quality.

After the velocital information metric is assigned to each frame, several alternatives are available for further processing. Higher quality images can be selected based on a preset threshold, or selected based on a percentage of frames to send. The threshold or percent selected can be automatically adaptive to ensure a steady stream of seamless images or it could be user controlled from either the receiver or transmitter location.

The approach defined above rejects poor quality frames. This could be thought of as doing an intelligent temporal subsampling. Typical temporal subsampling just skips frames regardless of whether those frames are high or low quality. As the results will demonstrate, compared to typical temporal subsampling the advantages of intelligent temporal subsampling is reduced digital artifacts, higher quality images, and reduced bits to transmit. Another advantage that is inherent in preconditioners is that the entire technique is in the front end so that no additional processing is needed on the receiver end.

3 The Compression of the Infrared Image Sequence

To demonstrate the velocital preconditioner, the H.261 compression technique is used along with Constant Bit Rate (CBR) encoding [6]. With CBR the encoded video rate is kept constant by adapting the quantizer scale based on the number of bytes in the encoder output buffer. The buffer to channel ratio is chosen to be 100 ms although different buffer sizes yield similar results. The 3 second infrared image sequence is preconditioned and 60 percent of the frames are selected for compression. For comparison purposes, the channel rate of the compression is accomplished at four different channel rates 200 Kb/s, 300 Kb/s, 400 Kb/s and 600 Kb/s.

For the demonstration, three frame sequences are compressed/decompressed: the original 99 frame infrared sequence, a 59 frame sequence produced from velocital preconditioning, and a 59 frame sequence produced from random temporal subsampling.

4 Measuring Preconditioner Success

The ability of a velocital preconditioner to provide higher quality output is demonstrated in several ways. One way is to observe the changes in the mean spatial and temporal information content. If noise is reduced, then the mean spatial and temporal information should be lower. For each image frame, we previously defined the spatial information feature [3] as $SI_{stdev}(t_n)$, which is the standard deviation over all the pixels in one frame after the frame is Sobel filtered. The mean spatial information content is then calculated as

$$SI_{mean} = \frac{1}{N} \sum_{t_n=0}^{N} SI_{stdev}(t_n) \tag{1}$$

where N represents the total number of frames under consideration. Likewise, the temporal information was previously defined as $TI_{stdev}(t_n)$, which is the standard deviation over all the pixels in one frame after the frame is differenced from the previous frame. The mean temporal information content is calculated as

$$TI_{mean} = \frac{1}{N} \sum_{t_n=0}^{N} TI_{stdev}(t_n) \tag{2}$$

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Another way to judge the results is to look at the reduction in bits being transmitted after compression. The number of bits transmitted should be less for a higher quality sequence. Obviously, the bits transmitted will be less just because frames are skipped. Therefore, the preconditioned sequence must be compared to a sequence of the same number of frames obtained from random temporal subsampling.

Another way to judge the success is to use an objective quality metric to judge the quality of the decoded video and compare that result with what is obtained from temporal subsampling and the original infrared image sequence.

Finally, another way to judge the success of the preconditioner is subjective assessment where side by side frames are examined for artifacts.

5 Results

For all three sequences (with or without preconditioning), the encoder output buffer overflowed when compression was done at a channel rate of 200 Kb/s. Figure 3 shows that the mean spatial information is reduced for the preconditioned sequence which is expected if the high information content due to erratic noise is discarded. On the other hand, Figure 4 shows that the mean spatial information is not improved if a random temporal subsampling is used instead of the preconditioner.

[width=6in]spat1.eps

Figure 3: The mean spatial information content is compared for the original 3 second infrared image sequence and the sequence obtained from the velocital preconditioner.

[width=6in]spat2.eps

Figure 4: The mean spatial information content is compared for the temporal subsampled sequence and the original sequence.

[width=6in]temp1.eps

Figure 5: The mean temporal information content is compared for the original 3 second infrared image sequence and the sequence obtained from the velocital preconditioner.

6 Conclusion

We introduced a velocital preconditioner for digital video compression which is shown to reduce the bits transmitted, reduced the digital artifacts, and reduce noise. Including this [width=6in]temp2.eps

Figure 6: The mean temporal information content is compared for the temporal subsampled sequence and the original sequence.

preconditioner as well as others in the compression/transmission recipe prior to encoding can lead to higher quality output without modifying the encoding/decoding algorithms.

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